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Striped Skinks in Oceania: The Status of *Emoia caeruleocauda* in Fiji[1]

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ABSTRACT: A rediscovered population of *Emoia caeruleocauda* from the Fiji Islands is compared with populations from Papua New Guinea, the Caroline Islands, and Vanuatu. Morphometrically, females from all populations are somewhat smaller than males, although males are significantly larger only in head length and width, and hindlimb length. Females and males do not appear dimorphic in scalation. Interpopulation comparison shows the populations to differ from one another in morphometry and scalation. In morphometry females and in scalation males and females of Fiji and Vanuatu and those of the Carolines and Papua are more similar to one another than each member of a pair is to members of the other pair. These patterns of variation suggest that the Fijian population of *E. caeruleocauda* is a native one and not introduced.

CURRENTLY, BIOLOGISTS recognize three striped *Emoia* from the oceanic islands of the south-central Pacific: *Emoia caeruleocauda, E. cyanura,* and *E. impar.* All three commonly have a dark dorsal background with a light middorsal stripe from the tip of the nose to the base of the tail; a pair of light dorsolateral stripes from the side of the head to the base of the tail; and a blue or green tail in juveniles. All three taxa occur together on some islands and can be broadly sympatric, although each tends to dominate in a different microhabitat. Owing to this sympatry and their similar appearances, the assignment of specific names to populations of these three species has been haphazard and further confounded by a proliferation of names for different insular populations.

Early in this century, workers (e.g., Sternfeld 1920, Burt and Burt 1932) recognized that the Pacific striped *Emoia* easily divided into two groups based on the number of subdigital lamellae. The "caeruleocauda" skinks have a moderate number of lamellae (<50 beneath fourth toe), whereas the "cyanura" skinks have numerous lamellae (>55). Further, the "cyanura" skinks occur throughout the tropical Pacific, but the "caeruleocauda" skinks were believed to occur only on the western edge, no farther east than Vanuatu and the Carolines. In the late 1970s, Pernetta and Watling (1979) reported *E. caeruleocauda* from two Fijian islands (Taveuni, Viti Levu) and considered the species to be a Fijian native. Brown (1991) was able to examine only four specimens for his monograph of *Emoia* and suggested that the species was probably an exotic for Fiji. Zug (1991) found only one voucher (collected in 1911) in the museums of the world and similarly considered the Fijian population as an introduced one.

This absence of vouchers stimulated our search for *E. caeruleocauda* in Fiji. We can now confirm Pernetta and Watling's report of a Taveuni population. There, *E. caeruleocauda* occurs abundantly in the native mountainside forest, suggesting that it is a native species. We examine this native versus exotic question further here through an analysis of scalation and morphometrics.

MATERIALS AND METHODS

Our comparison examines four insular populations: Caroline Islands (Pohnpei), Fiji (Taveuni), New Guinea (Morobe Province), and Vanuatu (Efate). Voucher and locality data are available in the appendix. The Fiji sample is the newly found population; the Vanuatu sample is the nearest-neighbor population to Fiji; the Caro-

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lines sample represents the *werneri* concept of *E. caeruleocauda,* used commonly from 1929 into the 1980s; and the New Guinea sample represents the *caeruleocauda* type concept although specimens are not from the type locality.

We recorded 10 morphometric and 10 scalation characters. These are as follows (recorded as in Zug [1991] unless noted otherwise): Measurements—EyEar, orbit to ear distance (anterior corner of eyelids to anteromedial edge of ear opening); HeadL, head length; HeadW, head width; HindlL, hindlimb length; Interorb, interorbital width (across top of head at suture of second and third supraciliaries); NarEye, naris-orbit distance (naris to anterior corner of eyelids); NeckL, neck length; SnEye, snout-orbit distance (tip of snout to anterior corner or junction of upper and lower eyelids); SVL, snout-vent length; TrunkL, trunk or body length; Scalation—BlwEye, supralabial scale lying below center of orbit; Dorsal, number of rows of dorsal scales between the parietals and base of tail, includes nuchal scales; Eyelid, number of enlarged upper eyelid scales; ForefL, number of digital lamellae beneath fourth digit of forefoot (the first proximal lamella counted is the first scale wider than long in contact with a large lateral/dorsal digit scale on at least one side); HindfL, number of digital lamellae beneath fourth digit of hindfoot; Inflab, number of infralabial scales; Midbody, number of scales around midbody; Supcil, number of supraciliaries; Suplab, number of supralabial scales; Supoc, number of supraocular scales. All measurements and counts were taken from the right side unless damaged; measurements to 0.1 mm recorded by dial calipers. All statistical analyses were performed on SYSTAT 5.03 (Wilkinson 1990); we used the Student's *t*-test to compare means and the Bartlett's adjusted χ^2 to test for homogeneity of variance.

RESULTS

Sexual Dimorphism

Adult female *E. caeruleocauda* are usually somewhat smaller (SVL) on the average than adult males but not significantly so for any of the four samples. All samples have HindlL, HeadL, and HeadW of the males averaging significantly larger ($P < 0.05$) than those of the females. In three samples (except Vanuatu), NarEye and EyEar mean lengths are also significantly larger in males. The Vanuatu males have significantly longer SnEye, which is also longer in males from the Carolines and New Guinea samples. Males in these latter two samples also have significantly wider Interorb. Covariance analysis with SVL as the covariate showed that the adjusted means for these characters remain significantly different ($P < 0.05$) between the sexes; indeed the significance increases in the adjusted means, with females proportionately smaller in all the preceding morphometric characters.

In scalation, no sexual dimorphism is apparent in the Fiji and New Guinea samples (Table 1). Males and females from Vanuatu show significant difference means for number of SupCil and Midb scales and for number of Eyelid scales in the Caroline sample. Because of the absence of concordance in these latter two samples and absence of any sexual differences in the Fiji and New Guinea samples, we interpret the four significant results out of 44 comparisons as stochastic events and not indicative of sexual dimorphism in our *E. caeruleocauda* samples.

Geographic Variation

Because of the sexual dimorphism of mensural characters, adult male and female samples were examined separately. For scalation, the samples included both sexes and a few immature individuals, because neither sex nor maturity affects the number of scales in an individual or sample.

Analysis of variance (ANOVA) revealed significant differences ($F > 3.0$; df = 3, 32) among localities for all mensural characters in females, and significant differences ($F > 3.0$; df = 3, 20) for only HeadW, NeckL, SnEye, NarEye, and Interorb in males. The general pattern for both sexes is that the Fiji and Vanuatu samples averaged somewhat larger than the Carolines and New Guinea samples.

To determine whether the characters with significant differences have any discriminatory content, we used principal components (PC)

TABLE 1

SUMMARY STATISTICS FOR SCALATION IN *Emoia caeruleocauda*

CHARACTERS	CAROLINES *n* 22	FIJI 14	VANUATU 20	NEW GUINEA 18
Supcil	9.0 ± 0.49 8–10	8.4 ± 0.63 8–10	8.2 ± 0.55 7–9	9.0 ± 0.34 8–10
Eyelid	10.2 ± 1.22 8–13	9.1 ± 1.35 7–12	9.2 ± 0.81 8–11	10.1 ± 1.08 9–13
Inflab	6.2 ± 0.40 6–7	6.4 ± 0.63 6–8	5.8 ± 0.37 5–6	6.1 ± 0.24 6–7
Dorsal	56.2 ± 0.92 54–58	57.7 ± 1.20 56–60	55.1 ± 1.43 52–58	55.8 ± 1.51 53–59
Midbody	30.0 ± 0.90 28–32	33.0 ± 1.41 31–36	31.1 ± 1.07 29–33	28.7 ± 0.96 28–30
FourfL	27.4 ± 0.87 26–29	26.3 ± 0.83 25–28	23.3 ± 1.38 21–26	23.9 ± 2.08 21–28
HindfL	40.0 ± 1.48 37–42	38.0 ± 2.48 33–41	35.2 ± 1.60 32–38	34.8 ± 2.71 30–39

NOTE: Character abbreviations are defined in the *Materials and Methods* section; values are mean ± standard deviation and range.

analysis to examine each sexual set by its "significant" characters. In females, the first three components explained 83% of the total variance, and all characters except HindlL loaded heavily (0.67–0.95) in the first component. Only HindlL strongly influenced (0.93; others <0.38) the second component, and only TrunkL (−0.60) and SVL (−0.40) weighed strongly on the third component. The first component was size-related, with size increasing from left to right on the component axis. There was no segregation of localities by the first and second components, but the first and third components (Figure 1) yielded a clustering of Vanuatu and Fiji, and the Carolines and New Guinea with only slight overlap of the two clusters. In males with a smaller set of "significant" characters, the first three components explained 92% of the total variance, and all characters loaded strongly (0.59–0.93) in the first component. Again this component was size-related. The second component was weighted mainly by NeckL (−0.69) and SnEye (0.74), and all characters weighed weakly (<0.33) on the third component. No segregation of localities was evident by first and second components or the first and third components in males.

ANOVA revealed significant differences ($F > 3.9$; df = 3, 70) among localities for all scalation characters that were not invariant within one or more samples. These characters are Supcil, Eyelid, Inflab, Dorsal, Midbody, ForefL, and HindfL. In general, the Fiji and Vanuatu samples averaged somewhat higher in number of Midbody scales and lower in Supcil and Eyelid than the Caroline and New Guinea samples. In other characters, different associations exist; for example, lower Inflab, ForefL, and HindfL linked the Vanuatu and New Guinea samples. Using these "significant" characters in a principal components analysis yielded a moderately distinct segregation of Carolines and New Guinea samples from the Fiji and Vanuatu ones (Figure 1) by first and second components; there was no segregation with first and third components. The first three components accounted for 71% of the total variance of the scalation data set. The first component loaded heavily with Dorsal, ForefL, and HindfL (0.72–0.89); the second component derived mainly from Midbody (−0.74), Supcil (0.69), and Eyelid (0.64), and the third component from Supcil (0.39), Eyelid (−0.48), and Inflab (−0.74).

DISCUSSION

All samples show sexual dimorphism of adult *E. caeruleocauda* in hindlimb length, and head width and length. Several other morphometric features (snout-eye, nares-eye, eye-ear, and interorbital distances) are also dimorphic in one

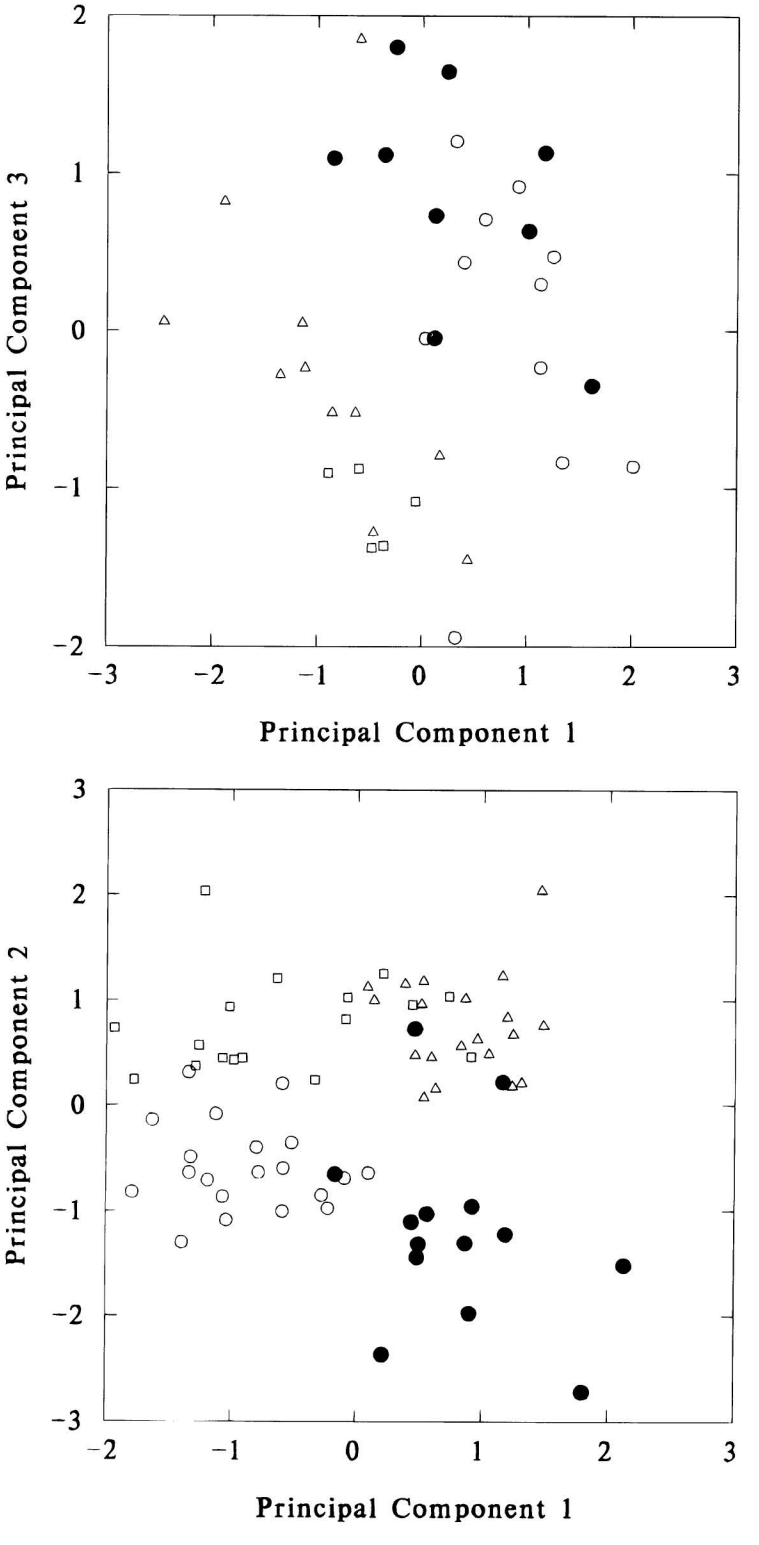

FIGURE 1. Phenetic affinities (principal component analysis) of *Emoia caeruleocauda* samples from four Pacific localities. Morphometric segregation of adult females (*top*) and scalation segregation of juveniles and adult females and males (*bottom*). Symbols: solid circle, Fiji; open circle, Vanuatu; open square, Caroline Islands; open triangle, Papua New Guinea.

or more samples. In all instances, adult females averaged somewhat smaller than adult males. Because of the morphometric dimorphism, females and males were examined separately. In females, the geographic affinities are between Fiji and Vanuatu, and the Carolines and New Guinea. The male morphometric data showed no segregation of sample localities, thus suggesting the unity of all samples. Scalation suggests the same affinities of Fiji-Vanuatu and Carolines–New Guinea as the female morphometric data.

We interpret these morphological data as confirmation of the naturalness of the Fijian population (i.e., not introduced recently by humans although a prehistoric transport is possible). The moderate segregation of Fiji individuals from Vanuatu ones (Figure 1) in scalation-multivariate space suggests a period of divergent evolution, again indicating a native, long-isolated population in Fiji. Although the data are indicative, our sample sizes are small and the four samples represent only a fraction of the geographic range of *E. caeruleocauda;* thus, we do not wish to overemphasize the differences observed. Certainly, our data do not permit any taxonomic action. We do note, however, that the larger samples of Brown (1991:tables 9–11) show the same association of Fiji-Vanuatu and Carolines–New Guinea samples. We also note that Brown's data suggest a differentiation of the Louisiade-Trobriand sample from his New Guinea one. Such differences require resolution before any taxonomic action because there may be a closer association of the Louisiade-Trobriand populations with the Solomons-Vanuatu-Fiji ones, further declaring the necessity of a broader sampling of the entire *E. caeruleocauda* distribution before taxonomic decisions.

Taxonomic Comments

Today's concept of the taxon *E. caeruleocauda* has a tortuous history throughout this century (see Brown [1991] for a detailed nomenclatural history). De Vis recognized and described this species from the Louisiade Archipelago of New Guinea in 1892. His name was either ignored or forgotten until the middle of the century, when Loveridge (1948) resurrected it for the New Guinean "*cyanura*" with low toe lamellae count. Loveridge noted that W. C. Brown had called his attention to the sympatry of *E. cyanura* and *E. caeruleocauda* on some Solomon Islands.

Apparently unaware of de Vis's *E. caeruleocauda,* Vogt (1912) described a striped skink from the Mariana Islands as the variety *werneri* of *E. cyanura.* Later, Sternfeld (1920) and Parker (1925) recognized that two different lizards were included in *E. cyanura,* and each selected an existing name (*E. kordoanum, E. lessoni,* respectively) for the low toe-lamellae taxon—names that subsequently proved to be incorrect. Schüz (1929) examined Vogt's Marianas type specimen (reporting 40 subdigital lamellae) and recognized *E. werneri* as a full species. He further described a subspecies (*E. w. trivale*) from northwestern New Guinea. Burt and Burt (1932) adopted Schüz's *E. werneri* concept, and *E. werneri* obtained common usage, persisting through the 1970s in spite of Loveridge's accurate assessment and assignment of names in 1948.

Although our data and analyses touch only superficially on the geographic variations within *E. caeruleocauda,* our interpretation of them suggests that *E. caeruleocauda* harbors several cryptic species. The following synonymy identifies the specific names currently available.

Emoia caeruleocauda de Vis

Mocoa caeruleocauda de Vis, 1892:12. Type locality: "Sudest [British New Guinea]" (Sudest can refer to either the Louisiade Archipelago, Papua New Guinea, or the island Tagula in this archipelago).

Lygosoma cyanurum var. n. *werneri* Vogt, 1912:5. Type locality: "Marianen" (= Mariana Islands).

Lygosoma werneri triviale Schüz, 1929:7. Type locality: "Doré auf New Guinea" (= Dore, Japen Island, Irian Jaya).

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APPENDIX

SPECIMENS EXAMINED

Caroline Islands, Pohnpei: MCZ 111494, 111496–99, 111502–3, 111505–07, 111509–10, 111512–13, 111515–16, 111518–20, 111523–24, 111529–30, 111532, 111535.

Fiji Islands, Taveuni: USNM 333793–806.

Papua New Guinea, Morobe Province: AMNH 66687, 66706, 66729–30, 92327–34, 92367, 95274–76, 95686–92, 103309, 105251–59.

Vanuatu, Efate: USNM 333941, 333943–49, 333959–62, 333953–66, 333968, 333970, 333972–73.